

G3/43

**JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY
PASADENA, CALIFORNIA**

RADAR MAPPING, ARCHAEOLOGY, AND ANCIENT LAND USE
IN THE MAYA LOWLANDS

R. E. W. Adams, W. E. Brown, Jr., and T. Patrick Culbert

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A severe incongruity has long existed between the well-known complexity of ancient Maya civilization and the relatively feeble economic base which could be reconstructed for it. Recent field work has indicated much more intensive subsistence patterns than had been previously found. However, limitations of archaeological work have combined with heavy jungle covering to restrict samples of information on ancient intensive cultivation patterns. Data from the use of synthetic aperture radar in aerial survey of the southern Maya lowlands suggest the presence of very large areas drained by ancient canals for the purpose of intensive cultivation. Preliminary ground checks in several very limited areas have confirmed the existence of canals. Excavations and ground surveys by several scholars have provided valuable comparative information. Taken together, the new data suggest that Late Classic period Maya civilization was firmly grounded in large-scale and intensive cultivation of swampy zones.

The Archaeological Problems

The large area of ancient civilizations now known as Mesoamerica contains the remains of many cultural traditions. Aside from the Maya there are those leading to the historically known Aztecs, Zapotecs, Tarascans, Mixtecs, and other groups of the 16th century. The zones occupied by these traditions, while large enough, are dwarfed when compared to the Maya lowlands. As traditionally defined, the area covers some 250,000 km² (Fig. 1). Because this zone is nearly all below the 1000-meter contour line, and receives heavy rainfall, exuberant vegetation has greatly hampered the use of rapid survey techniques such as aerial photography

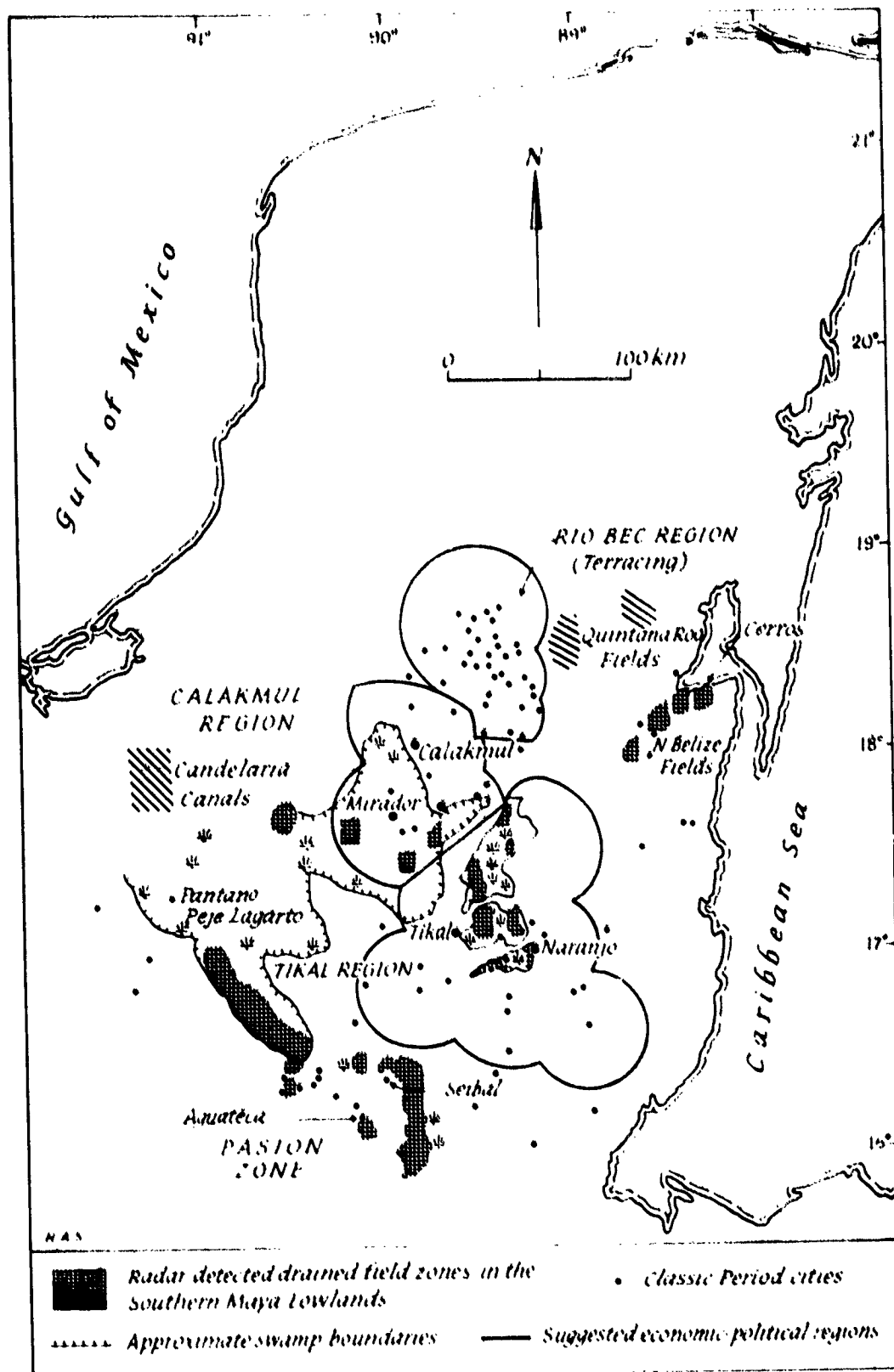


Figure 1. Map of the Maya lowlands showing drained field zones detected by radar in relation to known Maya cities of the southern and intermediate areas.

and wide-ranging ground reconnaissance. These constraints, in turn, have limited the perspectives of Maya archaeologists on regionalism and diversity within Classic period civilization. Indeed, even the sizes and reliability of samples of ancient cities are suspect. At the present, over 300 centers with formal architecture are known, ranging in size from one paved courtyard with attendant buildings to the largest known site, Tikal, which has the equivalent of 85 courtyards and hundreds of associated buildings (1). The most complex of these centers contain temples, palaces, administrative headquarters, fortifications, sculptured monuments with written texts, and large-scale reservoirs. These urban characteristics were fully developed by A.D. 250 if not before. Many centers are internally and externally linked by raised roads. Surveys of the countryside around these functional cities have developed evidence for large numbers of people, ranging up to 600 people per square kilometer in the most densely populated zones (2). These densities were certainly reached by A.D. 600 and perhaps as early as A.D. 100 in some regions.

A generation ago, the majority of archaeologists thought that the support of Maya population was a slash-and-burn system of agriculture similar to that practiced today by the sparse modern communities (3). In this extensive form of cultivation, fields are burned, cultivated for three or four years, and then abandoned to a period of fallowing lasting from eight to twenty years. In the past twenty years, data have increasingly indicated ancient populations of sizes far beyond the capacity of such a system to support. Many archaeologists have suggested a number of modifications which would help to close the gap between population and subsistence. For example, Puleston suggested that orchard cropping of *ramón* (*Brosimum alicastrum*) may have been a strong supplement to or substitute for maize as a staple food (4). Other mixes of subsistence systems have also been brought forward. In addition, evidence of intensive forms of

agriculture has been found. Extensive terracing of hillsides in the Rio Bec region, combined with field walls, has led Turner to conclude that the Maya in that region were entirely supported by intensive systems of agriculture by A.D. 600 and possibly earlier (5). Siemens and Puleston first found canals in the Candelaria Basin, and later in the Hondo River valley of northern Belize. Harrison's, Turner's, and Siemens' work has indicated that the extensive swamps of the Maya lowlands may also have been cultivated by means of canal drainage and raised fields (6). These data have been gathered mainly by aerial survey, although fields and canals have also been ground surveyed and excavated. However, the idea that the Maya were cultivating the vast swamps which constitute up to 40 percent of the land surface in some zones has been resisted by many. Puleston has argued that the aerially detected grid patterns are the result of soil expansion and contraction cycles which create patterns known as gilgai. Both Sanders and Puleston have also argued that aerial survey is not convincing evidence of the extent of ancient swamp drainage in the Maya lowlands, because the patterns can be the result of other, natural processes (7). Thus, while not denying that intensive cultivation based on drainage and raising of fields was practiced in certain zones, Sanders, Puleston, and others have remained unconvinced that such a system was in widespread use.

The theoretical implications are significant and complex. Briefly, they revolve around arguments as to the nature of Maya urbanism, the complexity and sophistication of Late Classic political systems, and the processes which led the civilization to its final disastrous collapse about A.D. 900. For example, the systemic model of the Maya collapse developed by the 1970 Santa Fe conference assumed a higher population than could be sustained on the basis of slash-and-burn agriculture, without a great deal of data indicating the intensive means by which they were sustained (8). Similarly, there was an assumption of a high

degree of political sophistication based on the numbers of people involved and on the managerial skills needed by intensive subsistence systems. Supporting data have been forthcoming, but were the interpretations of those data to be refuted, then grave doubt would be cast upon the cultural processes reconstructed by the collapse model.

It was with the idea of improving both the quality and quantity of the survey data for the Maya lowlands that we began casting about for a remote sensing technique that would be both rapid and reliable. Airborne, side-looking radar was among the techniques suggested to us. Bruce Dahlin contacted Walter E. Brown, Jr., at Jet Propulsion Laboratories, who provided access to such a system.

Concerning the Imaging Radar

The National Aeronautics and Space Administration owns and operates an imaging radar mounted on a CV-990, which is generally used to evolve spaceborne radars, such as the Apollo 17 Lunar Sounder (1971) and the SEASAT synthetic aperture radar (1978). The radar was originally designed and developed by the Jet Propulsion Laboratory in 1967 primarily as a sensor technique to be used to image the surface of Venus, expected sometime in the 1980s.

In the initial discussion of the use of radar for archaeology between Dahlin and Brown, the emphasis was on a sensor system that would penetrate foliage, silt, and root cover to map ancient man-made roads, causeways, and other structures. Previous work with this radar did not suggest an encouraging result to this experiment. The losses in microwave energy in the presence of moisture with high ion content, such as is found in the foliage and limestone in the Peten, were expected to be very high. However, we embarked upon an experimental program because the wavelength was larger than usual, 25 cm, and the effective peak power, 400 kilowatts, and the geometry such that we could look

almost straight down as well as off-nadir. There was some chance of success, and the need for an archaeological sensor was great.

Radar Description

The radar operates in a range-offset mode, with a center frequency of 1225 MHz. The major parameters of the radar are given in Table 1. The antenna is mounted on the rear baggage door. The effective antenna pattern is a fan beam 90 degrees cross-track centered at 45 degrees off-nadir, and 0.0057 degrees along-track centered at 90 degrees off the aircraft heading, looking out to the right side of the aircraft. To reduce the speckle effect inherent in coherent monochromatic systems, about twenty observations are averaged for an effective along-track angle of 0.11 degrees, or a 20-meter resolution in the direction parallel to the aircraft flight path at 45 degrees off-nadir. The term "synthetic aperture" refers to a technique which allows the experimenter to use a small antenna with a large angular coverage to generate a very long synthetic antenna and narrow the angular coverage by a factor of several thousand. The narrower the angular coverage, the better the angular discrimination, or the higher the along-track resolution.

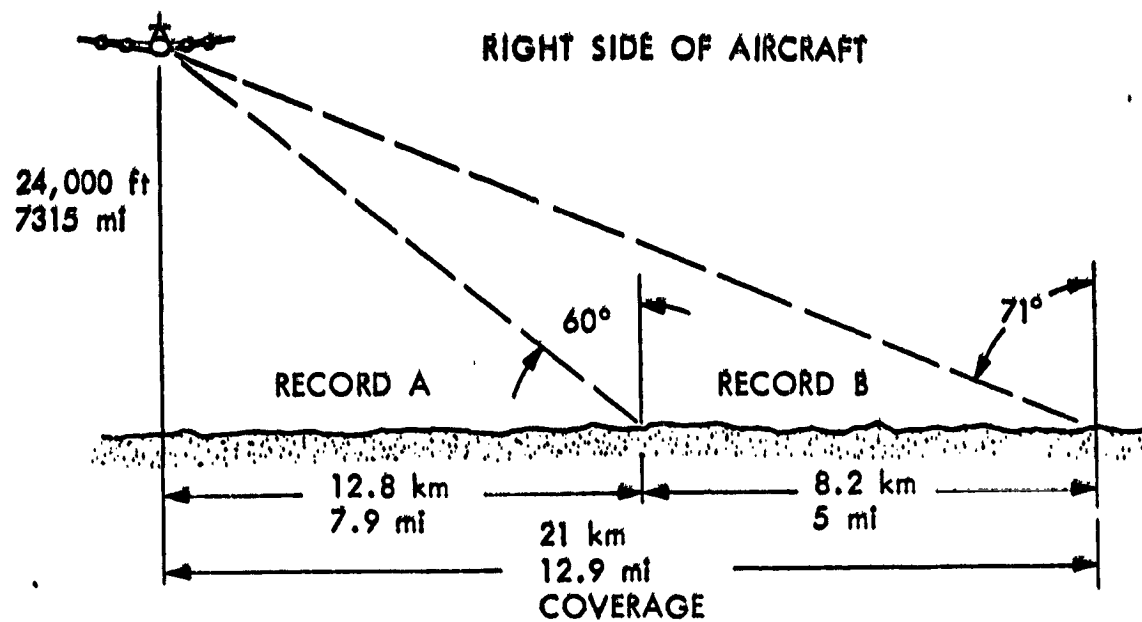
The range resolution is determined by the bandwidth of the radar system and is near 15 meters. At 45 degrees off-nadir, the cross-track resolution on the surface would be about 21 meters. A very good description of the synthetic aperture radar system is given by Jensen et al. (9).

Data Acquisition

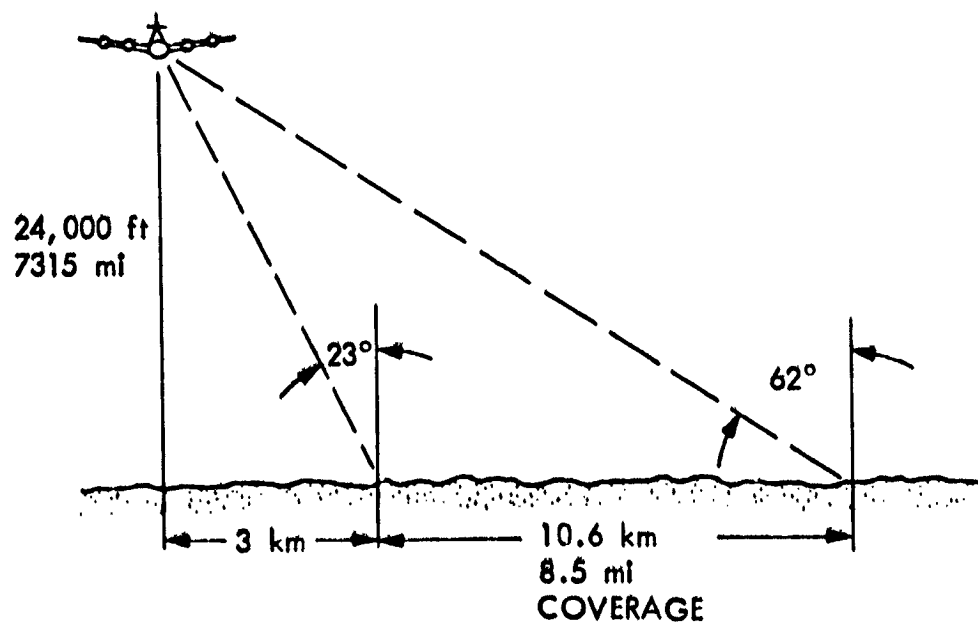
The JPL, L-band radar is mounted on the CV-990, a four-engine jet aircraft, operated by NASA Ames Research Center, Airborne Operations Group. The geometry for data acquisition in the area surveyed is shown in Figure 2.

Table 1. Parameters of Radar Imaging System

Radar Parameters	Characteristics
Frequency	1225 MHz
Wavelength	25 cm
Peak Power	4000 watts
Pulse Width	10 μ s
Bandwidth	20 MHz
Antenna Azimuth Beam	15 deg.
Antenna Range Beam	90 deg.
Recorder Type	Optical
Receiver Gain	80 dB
System Bandwidth	10 MHz
Range Compression Gain	2000
Azimuth Compression Gain	1500
Synthetic Aperture Length	750 m
Slant Range Resolution	15 m
Azimuth Resolution (single look)	8 m
<u>Aircraft Parameters (for Mayan Mission)</u>	
Altitude	24,000 ft.
Ground Speed (Nominal)	200 m/s
Time Marker	WWV (1 ms)
Inertial Guidance Accuracy	100 m
Camera Support	Black and white Infrared
Auxiliary Data	Flight logs, Ground track



a) 1977-1978



b) 1980

Figure 2. Radar acquisition geometry.

The radar views the surface from nadir out to 75 degrees from the right side of the aircraft, or a swath 17 km wide. The data are recorded on two recorders covering 0 to 50 degrees on one and 50 to 75 degrees on the other.

The data were obtained in October 1977, April 1978, and August 1980. The 1977 and 1980 flights were of short duration and covered northern Belize, Tikal, and the Pasión River. The 1978 flights were a five-day sequence and covered northern Belize and virtually all of the Peten. During this sequence, black-and-white air photos and false color IR were also taken. About 20 percent show the surface well; the remainder are degraded by haze and clouds. During operations, the coordinates are preset into the navigation system and flight conducted at an altitude of 24,000 feet along the preset tracks, even though the ground may be completely obscured by cloud cover.

Data Processing

All of the radar data were initially recorded optically. The data base is, therefore, radar echoes in a range-doppler format and must be correlated to produce imagery. The correlation was performed on the optical correlator at JPL with a system configured for SEASAT, a spacecraft imaging radar. The delay of about a year in processing was the result of a reconfiguration effort for SEASAT. The doppler aperture is about 10 to 15 cm long on the film, and the SEASAT correlation can handle about 3 to 5 cm. Therefore, the full azimuth resolution was not realized on the data thus far correlated. Full processing is planned later this year. A test on the August 1980 data with about 8 cm of the doppler history processed is shown in Figure 3. This area shows a region around Tikal, the road, and airstrip. The Temple of Inscriptions and other major structures can be clearly seen.

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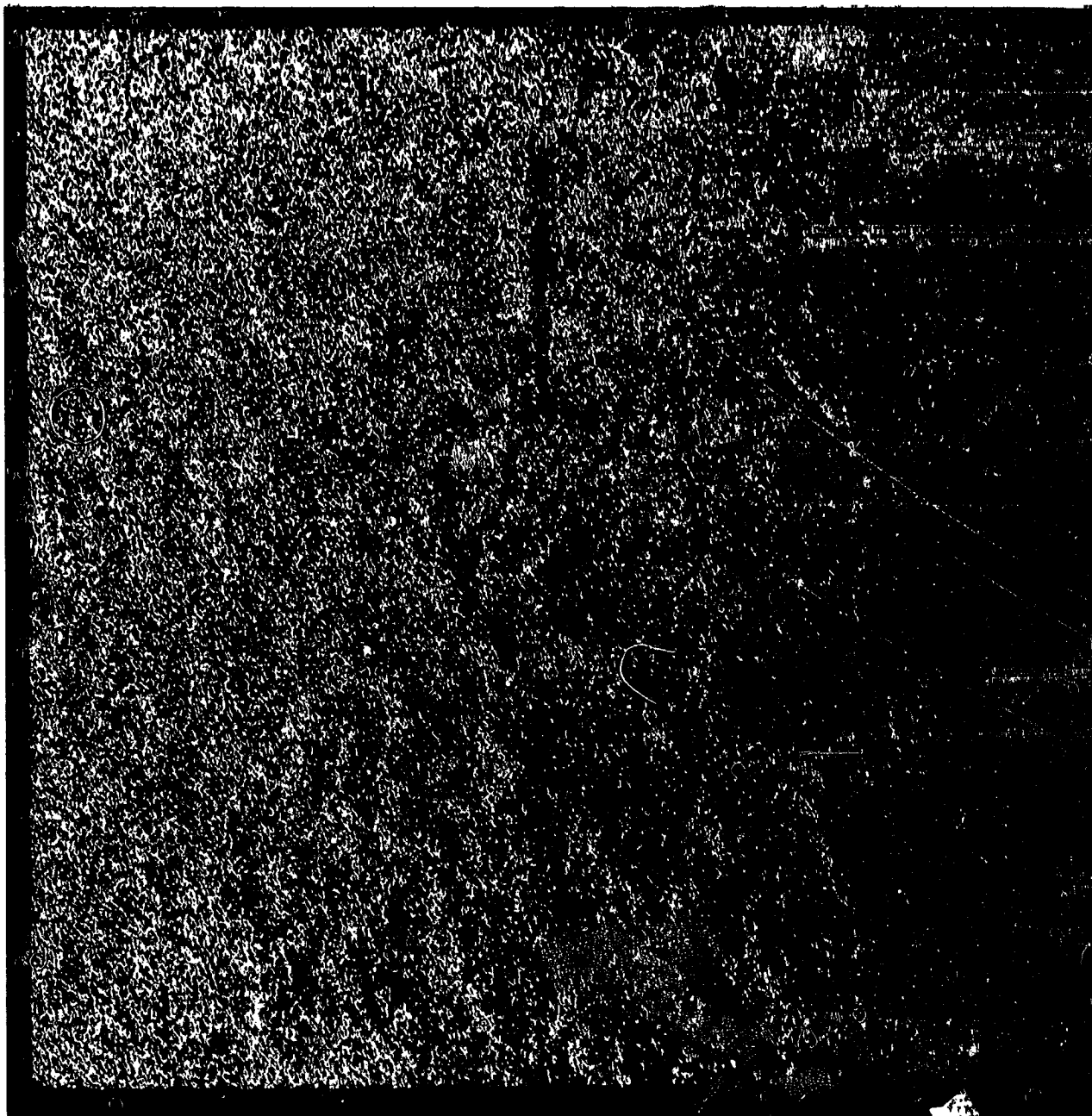


Figure 3. Synthetic aperture radar imagery of the Tikal zone, Guatemala. Heavy, dark horizontal line is the Tikal airstrip. Main ruins show as a set of bright dots about 1 inch to the left of the end of the airstrip. Scale ca. 1:75000.

The initial intent of the mission was to seek effects caused by structures hidden beneath the canopy (Dahlin's main interest) and agricultural signatures (Adams and Culbert). So far, only a very faint indication of the causeways in the Mirador area have been identified by Dahlin, and the effects of agricultural activity described herein.

Analysis of the Radar Imagery

The senior author has been responsible for the analysis of the imagery. Positive print negative films of the radar imagery were examined on a light table for indications of archaeological sites and ancient landscape modification. A ten-power handglass was used. Light passing through the imagery was subdued by covering it with medium thickness tracing paper. This procedure helped to reduce the effects of "speckle," an inherent radar image phenomenon. Data were manually transcribed onto tracing film with a mapping pen, and the resultant overlays compared with several sorts of topographic data. The overlays were placed directly onto maps of the same scale, and compared with maps of more detailed nature, as well as with aerial photos of specific zones.

Archaeological sites show up in two ways: as one or more blips of light, or as distinct shadows cast by large mounds. Dots of light show only on sites with large buildings on which the casings have either survived or been restored. Most sites do not have these features. At the present scale of 1:250,000 it is difficult to distinguish shadows of large mounds from shadows cast by natural hills, in all but the largest sites. These difficulties in site detection seem to be mainly a problem of scale of resolution, and the improved imagery from the 1980 flight gives hope of more detailed data from future missions.

It was noted that areas of wet season swamp (bajo) near known sites often had irregular grids of gray lines within them. Upon careful examination, these

lines were seen to form a multitude of ladder and lattice patterns, as well as curvilinear patterns. Overlays of these zones (e.g., northern Belize, Fig. 4) were compared with overlays of aerial views of confirmed ancient canal systems from the Valley of Mexico and the western Maya lowlands (the Candelaria River, Fig. 5). Allowing for scale differences, the patterns from radar and aerial views are the same. This suggests that at least some of the grid patterns produced by the radar are ancient canals. The scale differences also strongly indicate that only the largest and most widely spaced canals are picked up by the radar.

Further pattern analogy which tends to confirm the interpretation is that the grid lines in the swamps and along the watercourses have the same visual quality as do abandoned stream channels. Moreover, grids are closely associated and correlated with the known areas of swamps, edges of lakes and ponds, and along watercourses. There is a negative correlation between grids and areas of upland, karst landscape, and mountains. Finally, aerial identifications of grid and linear patterns within the swamps have been made by Turner, Harrison, and Siemens separately, and at widely different points within the areas covered by radar imagery.

Lest the reader conclude that there is an invariable one-to-one relationship between the radar imagery, aerial photos, and ground features, let us state that there is not. The radar does pick up individual large canals, as it has done at Cerros and near Seibal. Aerial photos show many of the same canals, but in much greater detail and with many more of the smaller, interstitial canals (Fig. 6). Ground checks almost always deal with fragments of major canals, and much more with the interstitial canals which are on aerial photos, but rarely on radar imagery at this scale of resolution.

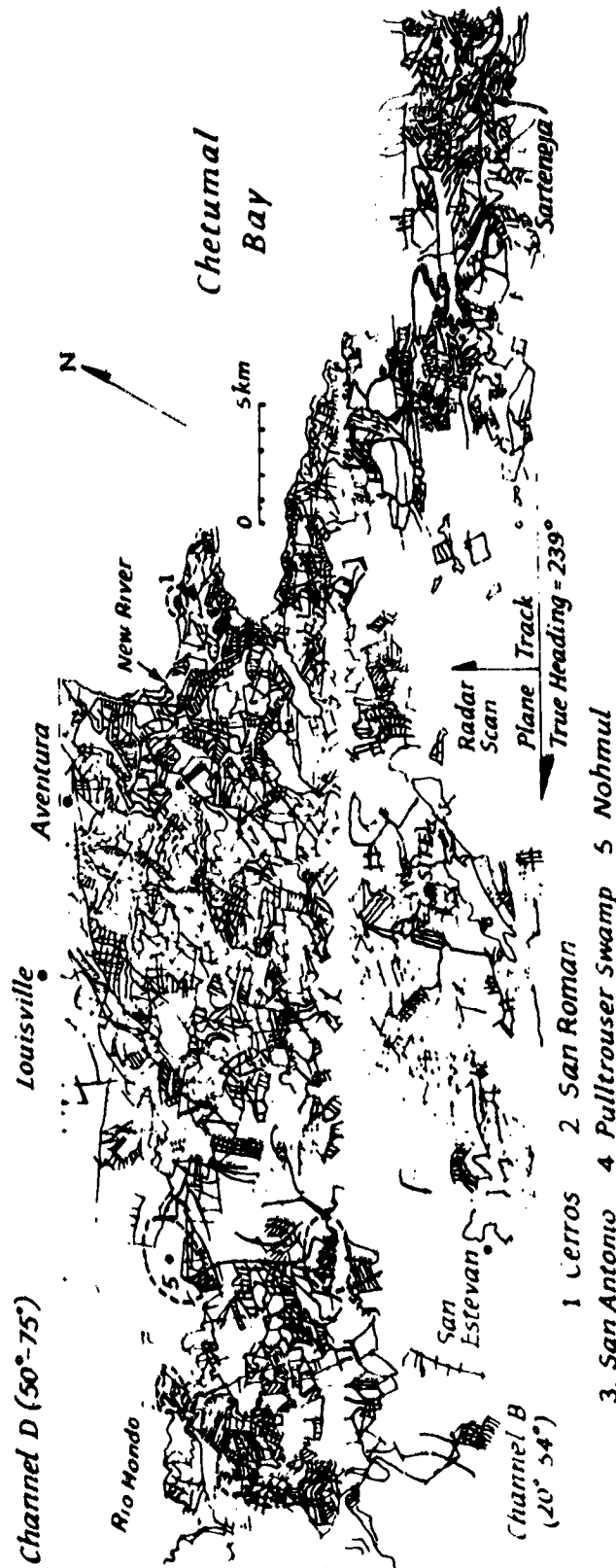


Figure 4. Overlay of northern Belize transcribed from radar imagery showing lattice structure of canal lines, and the five zones of ground confirmation.



Figure 3. Overlay of a low level oblique aerial photo showing confirmed ancient canal patterns in the Candelaria River zone of the Maya Lowlands. Scale ca. 1:1000.

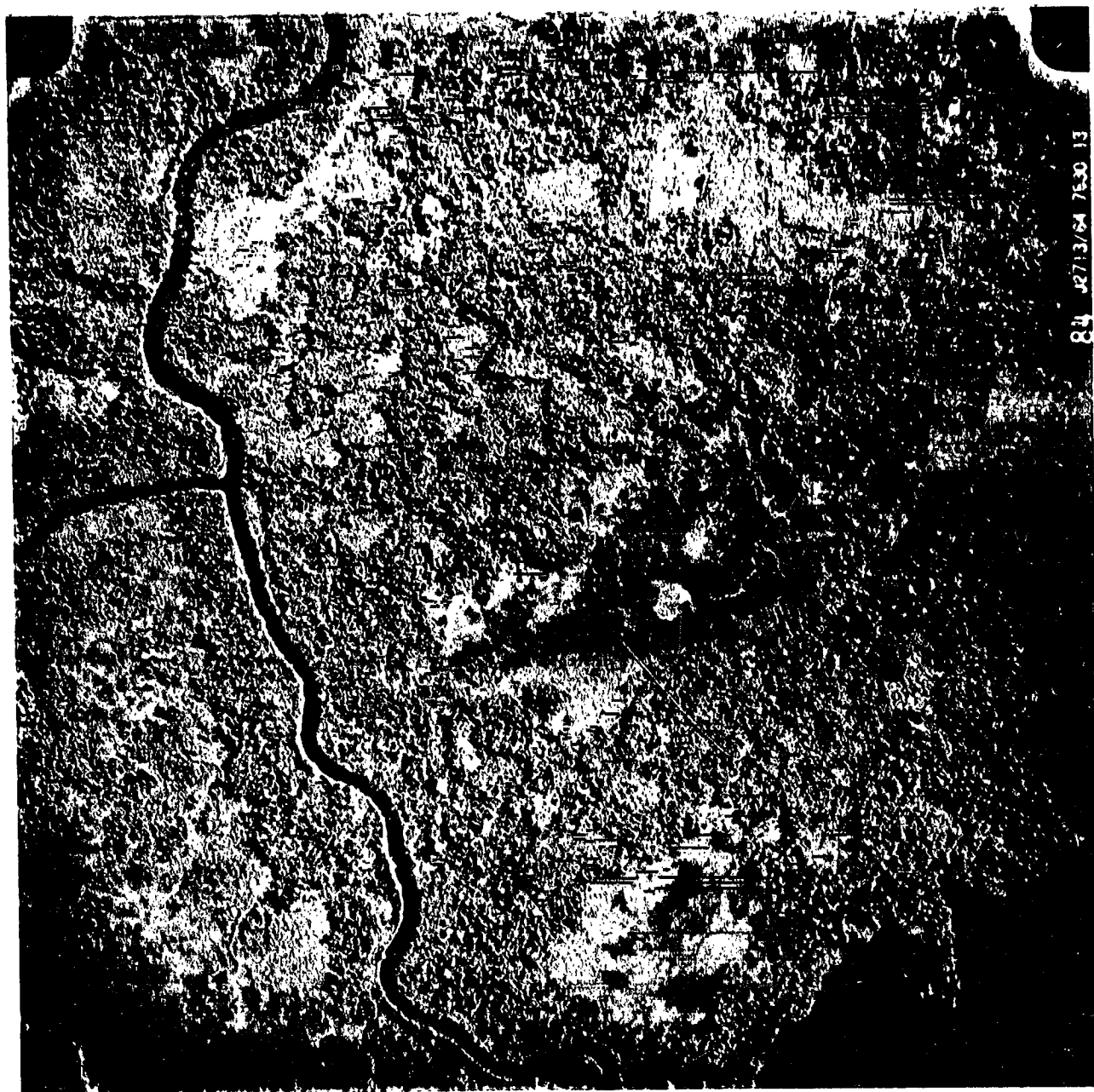


Figure 6. Aerial photo of the San Roman swamp zone of northern Belize along the Rio Hondo. Ancient raised fields and canals are visible as cellular patterns in lower right center. Scale ca. 1:2000. (Courtesy Belize Sugar Industries.)

Pattern analogy is not proof, of course, nor have visual and aerial photographic data convinced all archaeologists. Therefore, ground checks have been carried out by Adams and Culbert, together with H. W. Lende, and T. C. Greaves. Other ground confirmations have been kindly provided by colleagues.

Five separate zones in northern Belize (Figs. 4 and 6) have been ground confirmed as locations of ancient canals and raised field systems. Confirmations, sources, and data are summarized in Table 2. It should be noted that the five zones of confirmation are all covered not only by radar imagery, but also by visual and aerial photography, in addition to ground checks. Further, it is important to note that the five confirmations have been made by five separate groups of archaeologists. One of the most important sets of findings is that provided by the work of Vernon Scarborough at Cerros (10). At this site, the major canal surrounding the site clearly shows up in the imagery. The site also contains raised fields, although they do not show in the imagery because of the scale of resolution. The fields are about 3 meters on a side and the minimum object definition obtainable with the present data is 15 meters. Scarborough's data indicate that there are a great many other items recorded by the radar. These non-archaeological features include modern road nets, old logging trails, hurricane beach swales, abandoned jungle airstrips, river terrace edges, and fault lines. However, it is significant that none of these or other non-archaeological features show the characteristic grid, ladder, or lattice patterns associated with known canal areas. Besides canals and large mounds as already noted, the edges of extensive paved surfaces are detectable. Overlays produced from the imagery must be filtered by pattern analysis after all data are taken from the negative images. Analysis of twenty overlays thus far indicates that between 20 and 40 percent of the lines have the required pattern characteristics and therefore are probable canals.

Table 2. Summary of Ground Check Confirmations in Northern Belize

Zone	Major Site	Coverage ¹	Source
1. Cerros peninsula	Cerros	Ra/AP/GC/EC	Friedel, Scarborough, personal communication
2. Pulltrouser Swamp	None	Ra/AP/GC/EC	Harrison, Turner, personal communication
3. Nohmul	Nohmul	Ra/AP/GC	Hammond 1973
4. San Antonio	None	Ra/AP/GC/EC	Siemens & Puleston
5. San Roman	None	Ra/AP/GC	Adams & Greaves

Note 1. Abbreviations for types of coverage:

Ra, radar; AP, aerial photography; GC, ground check; EC, excavation confirmation.

Harrison and Turner's work at Pulltrouser Swamp is particularly important because it is the first extensive excavation of raised fields carried out in a lowland swamp, demonstrating that the canals are indeed artificial, ancient, and associated with raised field agriculture. These canals and fields show up in the radar imagery as well as in aerial photos, with the caveats on detail as noted before. In other words, as in all cases, the radar gives a gross idea of the presence of canals and fields, but at present, not a great deal of detail.

Swamp zones along the present stream beds, such as the San Roman swamp on the Rio Hondo, are annually flushed by floods. No cultural remains are likely to be found in such cases, and only pattern analogy with excavated swamp and lake-side fields can indicate the former function of grids in such circumstances. Adams and Greaves found only regular islands of swamp grass with the water grids at San Roman (Fig. 6).

Hammond, in 1973, found canals and raised fields near Nohmul. Puleston and Siemens also found the same at San Antonio on the Rio Hondo.

The data from northern Belize are thus convincing and strong in their confirmation of the interpretation advanced herein. The data from the Guatemalan Peten zone are less satisfactory.

Three Peten zones were ground checked in February-March 1980 by Adams, Culbert, and Lende. These results are summarized in Table 3. One zone is on the south edge of Lake Petexbatun and associated with the major site of Aguateca. The swamp shows some regularity of water channel patterns both from water level and from low-level flight. However, no cultural material was found.

The zone north of the Pasión River in the vicinity of the site of Seibal was also explored. The Arroyo Cantemó, evidently a major canal, was explored by dugout canoe. Tributaries, which are long and linear and enter the Arroyo Cantemó at right angles, were noted from the canoe, from low-level aerial observation and photos, and from high-level photos. No cultural material was found during the brief ground exploration. The third zone examined in the Peten was around the very large center of Tikal (Fig. 3). Swamps gird this center and the edge of the Bajo de Santa Fe to the east was briefly examined by Adams and Lende, who found what is apparently a raised field, and some apparent canals. The raised

Table 3. Summary of Ground Check Confirmations in the Peten, Guatemala

Zone	Major Site	Coverage ¹	Source
1. South Petexbatun Swamp	Aguateca	Ra/AP/GC	Adams, Culbert, Lende
2. Great Bend, Pasión River	Seibal	Ra/AP/GC	Adams, Culbert, Lende
3. Bajo de Santa Fe	Tikal	Ra/AP/GC	Adams, Lende

Note 1. Abbreviations for types of coverage:

Ra, radar; AP, aerial photography; GC, ground check.

field is approximately 30 meters wide, 2 meters high, and more than 100 meters long. The apparent canals are heavily obscured by vegetation. A possible canal was seen about 12 kilometers north of the center of Tikal on the trail to Uaxactun. This is probably part of the northern "fortification" ditch (11). Our panchromatic coverage of the Bajo de Santa Fe near Tikal and in the Selbal zone shows the presence of grid patterns identical to those found in the northern Belize zones.

The lack of better results in the Peten zones compared to those from Belize is due to two related factors: the much denser and higher forest cover in the Peten, and the relatively small scale of resolution in the radar imagery. However, low-level flights over rush and sedge swamps in a zone of the Peten between the Rio de la Pasión and Laguna Mendoza show definite grid patterns and lines within those swamps. Figure 1 illustrates the distribution of radar-detected canals thus far found in the southern Maya lowlands.

To summarize, we have produced confirmation by aerial photography, visual reconnaissance, and ground checks of the existence of ancient canal systems in five zones in northern Belize, and less certainly, in three zones in the Peten of Guatemala where they were indicated by the radar survey. These confirmations amount to pinpoint checks when compared to the total amount of area covered by radar imagery. However, with the technique proved valid, the question becomes one not of the widespread existence of canals, but of their total extent. Radar imagery gives us preliminary and tentative estimates of that dimension. Although further analysis and new imagery with higher resolution are needed, the data now in hand allow us to set the probable minimum and maximum extents of Late Classic canal systems.

Applications of the New Data

The total area of the Department of Peten in Guatemala is approximately 36,200 km², nearly all of which was covered by radar survey. Another 670 km² was covered in northern Belize, for a rounded up total of approximately 37,000 km². Approximately 8,000 km² of the Peten is estimated to be periodic swamp. Another 6,000 km² of land needs drainage for agricultural purposes (12). This total of 14,000 km² represents the outside theoretical limit of canal-drained land in the surveyed area. Since human systems rarely comprehend the totality of the natural phenomenon with which they deal, it is reasonable to suppose that the actual maximum was less than the theoretical figure. Judging by the radar imagery, nearly all swamps, watercourse edges, and surrounds of lakes and ponds in the Peten have been modified by drainage canals, except, possibly, in the northwestern sector. Omitting this zone (ca. 1,575 km²) from the calculation leaves a theoretical maximum of 12,425 km². The Bajos de Santa Fe, Azucar, and Maquina in the area east, north and south of Tikal show the greatest density of canals. Another major zone is that which is just east of the Sierra de Lacandon, running from the Pasia River north to the Pantana Peje Lagarto. Assuming that only 20 percent of the radar-detected lines are actual canals, based on the Cerros assessment, then an adjusted maximum of 2,475 km² is reached. This adjusted figure is based on the total area that would require drainage for agriculture. Estimation of the minimum area requires using only the swampy zones as a calculation base (8,000 km²), and yields a figure of 1,285 km² (8,000 - 1,575 × .20). In spite of the apparently drastic reduction of the figures, both are very large for pre-industrial irrigation or drainage enterprises. For comparison one must look to the well-known Aztec chinampa system, which covered only 120 km². However, the population estimates for the Valley of Mexico are much lower than those for the Maya lowlands, 1.5 million, and areal extent (7,833 km²) only a little over

10 percent of the southern Maya lowlands (75,000 km²) (13). Therefore, there are proportional and correlated differences in sizes of total area available, total area intensively farmed, and total population sustained. We assume here that most of the drained field areas were in simultaneous use in the late Classic (A.D. 600-900), the period of demonstrated maximum populations. This assumption could be in error lacking extensive excavation data.

The new radar data provide new perspectives on Maya civilization in several ways. First, there is the possibility that the southern lowland Classic Maya were the largest-scale users of intensive cultivation systems in Mesoamerica. Second, problems of locational analysis become simpler when applied to Maya centers. Swamps are recognized as assets instead of waste land; indeed, perhaps the most productive land available. Modern experimental plots in lowland Veracruz have produced data on the productivity of such systems in tropical forest environments. It is estimated that a hectare of land cultivated by the raised field and ditch system will support a minimum of ten persons (14). This means that the locations of the largest sites such as Tikal, on the edges of the largest swamps, can be explained as the result of successful exploitation of a nearby rich resource. Third, the economic basis for Maya civilization, and specifically for the great numbers of people implied by settlement pattern surveys, becomes more convincing and coherent in its structure. Fourth, canals through shallow lakes and swamps could have provided means of transport for bulk commodities. This combined function of water control and transportation route is well known for the traditional canal systems of Southeast Asia, as well as for the historical Aztecs. Such a facility to transport would aid in explaining the support for the masses of people in the pre-industrial cities of the Maya; 50,000 at Tikal alone (15). Additionally, but not exhaustively, the use of an intensive sophisticated system of agriculture which required considerable management may also

explain at least part of the vulnerability to the systemic collapse that the Maya suffered about A.D. 900.

We recognize the present work to be preliminary, although provocative. The imagery represents a large-scale dimension of ancient land use that has not been available before. As such, it also presents us with problems of full validation. The immense area covered means that it will be some time before an adequate ground check can be made of all the canal areas indicated. Further, although there has been some excavation of raised fields in Belize and in the Candelaria zone, a great deal more digging is needed (3,6). Only excavation can produce more precise estimates of the total areas of raised field growing surfaces in any given period. Excavated data are also needed on population within the raised field zones, as well as detailed information on water and land management techniques. Excavation at hamlets associated with raised field zones would throw light on such matters as stone technology, food crops, and developmental trajectories of the canal systems.

Finally, the new information allows the possibility of more effective land use planning by the modern governments of Guatemala, Belize, and Mexico. These nations are using the Maya lowlands as their last frontiers and their people are moving into the zones in great numbers in both planned and unplanned agricultural colonies. Yet, there is no long-term historical experience to consult in regard to permanent, intensive agriculture in these tropical forest areas. Now radar technology and archaeology may combine to provide at least some of the data needed for rational land use plans, as well as avoidance of some of the mistakes and disasters of the past.

R. E. W. Adams
Churchill College, Cambridge University

W. E. Brown, Jr.
Jet Propulsion Laboratory

T. P. Culbert
University of Arizona

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16. Acknowledgements. This report represents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology, under Contract NAS 7-100, sponsored by the National Aeronautics and Space Administration. We thank NASA, JPL, Churchill College of Cambridge University, England, and the Lende Foundation of San Antonio for their support. The governments of Guatemala and Belize gave both support and permission. We also thank Nelson Milder and the Technology Transfer Office of NASA, Louis Haughney and the flight support crew, Frederick Drinkwater and the flight crew of the NASA CV-990 of Ames, Thomas Bicknell and Thomas Andersen and the data reduction team, Col. Rene Aguiluz and Sr. Raul Lee of the Instituto Nacional Geografico de Guatemala, Sra. Vivian Broman de Morales, Lic. Francis Polo, Vernon Scarborough, Thomas R. Hester, Norman Hammond, B. L. Turner, II, David Freidel, Edmundo Solis, Col. Thomas Kelly, Harriot Topsey, Mark Gutchen, Belize Sugar Industries, and many others who aided our work.

Figure Legends.

1. Map of the Maya lowlands showing drained field zones detected by radar in relation to known Maya cities of the southern and intermediate areas.
2. Radar acquisition geometry.
3. Synthetic aperture radar imagery of the Tikal zone, Guatemala. Heavy, dark horizontal line is the Tikal airstrip. Main ruins show as a set of bright dots about 1 inch to the left of the end of the airstrip. Scale ca. 1:75000.
4. Overlay of northern Belize transcribed from radar imagery showing lattice structure of canal lines, and the five zones of ground confirmation.
5. Overlay of a low level oblique aerial photo showing confirmed ancient canal patterns in the Candelaria River zone of the Maya lowlands. Scale ca. 1:1000.
6. Aerial photo of the San Roman swamp zone of northern Belize along the Rio Hondo. Ancient raised fields and canals are visible as cellular patterns in lower right center. Scale ca. 1:2000. (Courtesy Belize Sugar Industries.)